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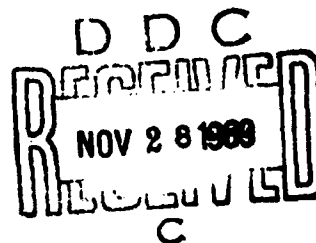
Human Factors in Airmobility

by

Wallace W. Prophet

Presentation at the
Army Scientific Advisory Panel
Fort Rucker, Alabama May 1969

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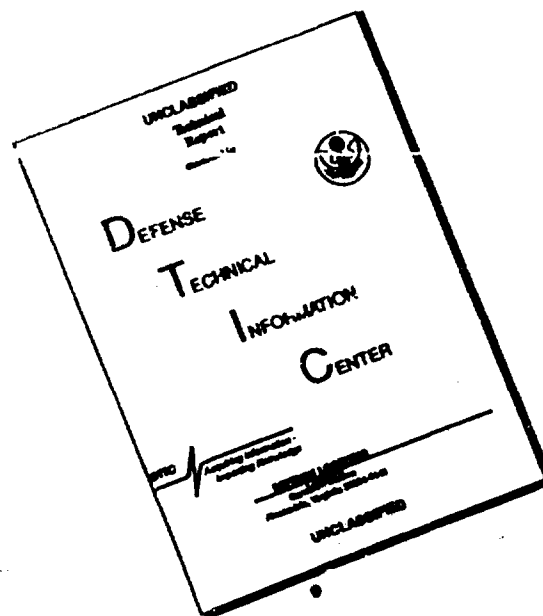


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Prefatory Note

This paper is based on a presentation at the spring meeting of the Army Scientific Advisory Panel held at Fort Rucker, Alabama in May 1969, with the U.S. Army Combat Developments Command Aviation Agency as host. The general theme was "Achievements, Trends, and Challenges of Organic Army Air mobility." The paper describes the general organization of the Army's human factors research program, the research program of HumRRO Division No. 6 (Aviation), and certain human factors research areas of significance to Army air mobility during the 1970-1980 time frame.

The research by HumRRO Division No. 6, Fort Rucker, Alabama, that is described in the paper is based on studies performed under Work Unit PREDICT, Correlational Analysis of Aviator Performance; Work Unit MANPROBE, Human Information Processing Requirements in Manned Aerial Reconnaissance and Surveillance Tasks; Work Unit UPGRADE, Improving Aviation Maintenance Training Through Task and Instructional Analysis; and Work Unit SYNTRAIN, Modernization of Synthetic Training in Army Aviation.

HUMAN FACTORS IN AIRMOBILITY

Wallace W. Prophet

In this presentation I will seek to highlight a factor in Army airmobility that is sometimes overlooked, the human factor. In aviation, as in the rest of the Army, the men—the mechanics and pilots—remain the most important part of our complex man-machine systems.

The representative of the Aeromedical Research Laboratory has discussed medical research programs treating the man in the system. My paper will cover selected aspects of the current activities and future challenges of another part of the Army's research in regard to the man in the system, the behavioral and social science research program.

While there were certain behavioral science applications in the military as far back as World War I, it was during World War II that behavioral and social science research emerged as a significant factor on the military scene. As military systems and equipment have become more sophisticated and expensive, it has become increasingly necessary to consider human capabilities and limitations in their design and operation. The time is long past when we could assume that man's almost infinite behavioral flexibility could make the adjustments necessary to make a poorly designed system work. Man-machine compatibility is more than an impressive phrase; it is often the critical factor in determining mission success of a system.

Designing for man in a military system must go far beyond the obvious aspect of engineering compatibility of man and machine. It must include design of appropriate personnel and training systems. We must consider our trainee and his aptitudes, and we must manage our manpower wisely. Why? There are the obvious factors related to the need for appropriate operator skills and knowledges required for mission success. Consider, in addition, what military training costs. During the FY 69 fiscal year, the Department of Defense budgeted over \$4.4 billion for training, and over one-third of that total was to support flight training. Thus, efficient design for the human factor must include training and personnel system design as an integral part of weapons system design. Army flight training and personnel costs are reasonably modest when compared with those of our sister services, but they are substantial and the trend is upward.

Human Factors Research in the U.S. Army

In seeking to design more effectively for the man in the system, the Army has organized a comprehensive program of research and application in the human factors and social science areas. Basic guidance for

this program is set forth in U.S. Army Regulation 70-8.¹ The objectives of the program described in the regulation are:

(1) Improved functioning of man in the Army through behavioral science and operations research and development conducted in the broad areas of human performance, manned systems, and personnel measurement and evaluation.

(2) Improved performance of Army personnel through research and development in the fields of training methods, techniques, and devices.

(3) Improved motivation and leadership through studies in those fields.

(4) Improved compatibility of men and the weapons, equipment, and systems which they are required to operate and maintain, through basic, applied, and operations research in human factors engineering and man-system analysis.

(5) Improved performance and capabilities through social and behavioral sciences research and development. This encompasses research and development in support of psychological operations, civil affairs, internal defense, civic action, intercultural relations, and military assistance.

(6) Support of operational capability objectives (OCO), qualitative materiel development objectives (QMDO), advanced development objectives (ADO), qualitative materiel requirements (QMR), small development requirements (SDR), and Army research plans (ARP).

The program is administered by the Chief of Research and Development through the Behavioral Sciences Division of the Army Research Office. Agencies include in-house laboratories with both military and civil service psychologists, as well as separate contract research laboratories.

The first program objective—that having to do with personnel measurement, evaluation, and selection—is principally the responsibility of an in-house agency, the Behavioral Science Research Laboratory (BESRL). BESRL has made a noteworthy contribution to Army airmobility through the development of the Flight Aptitude Selection Test Battery.

The second and third program objectives—those having to do with training methods, techniques, and devices and with motivation and leadership—are primarily the responsibility of the agency I represent, the Human Resources Research Office, or HumRRO as we are usually called. HumRRO has been a research agency of The George Washington University and is now being organized as an independent nonprofit organization.

¹Department of the Army. *Human Factors and Social Science Research*, Army Regulation 70-8, Washington, November 1965.

From its inception in 1951 to 1967 HumRRO operated exclusively under contract to the Army. In 1967 an agreement was reached with the Army to allow HumRRO to work for additional sponsors. Under this arrangement, we have worked for such diverse sponsors as the U.S. Post Office Department, the Louisiana State Tumor Registry, and the U.S. Coast Guard. Under this last sponsorship, the HumRRO Aviation Division is conducting a study of Coast Guard aviation training and device requirements.

I would like to comment briefly, for those of you who are interested in organizations and research management, on our somewhat unusual—perhaps unique—organizational arrangement with the Army. HumRRO has seven research divisions, five located at major Army installations. At each of the five field locations there is a collocated military agency, an Army Human Research Unit, that provides military support and guidance for the research program. The technical aspects of the research are under the direction of a HumRRO Director of Research, while the Human Research Unit is directed by a military Chief, an Army lieutenant colonel. Neither the Chief nor the Director of Research has authority over the other, and they must work together closely in support of mutual research goals. A number of outside observers have commented on this strange symbiosis, but whether you view it as ecology or just plain eclecticism, it works!

The fourth human factors objective area—man-equipment compatibility—is carried out by several Army Materiel Command Laboratories, the largest being the Human Engineering Laboratories (HEL). While HEL has studies supporting many areas of hardware development, in recent years an increasing proportion of their activity has been devoted to aviation systems. Their aviation studies have ranged from design of the helicopter cyclic grip to analysis of crew information requirements for helicopter instrument flight.

The fifth program objective is concerned with areas such as psychological operations, civil affairs, intercultural relations, and military assistance. This research mission is performed by several research agencies, including HumRRO. The principal agency, however, is the Center for Research in Social Systems, or CRESS, of the American University in Washington, D.C.

The final program objective, that of support of various specific Army requirements and developments, is, of course, the joint responsibility of all the agencies mentioned, BESRL, HumRRO, HEL, and CRESS. This "family" of human factors research agencies provides the Army with broad subject matter coverage, as well as making available human factors expertise for consultation on specific application requirements. As in any scientific area, the applications must be based on a sustained, sound, and viable research program.

The Army has taken specific steps toward assuring the appropriate application of human factors information developed by these and other research agencies. Of particular relevance are the following guidance documents: U.S. Army Regulation 602-1, *Human Factors Engineering Program*, March 1968; Department of the Army Pamphlet 11-25, *Life Cycle Management Model for Army Systems*, October 1968; Human Engineering

Laboratories Guide 1-69, *Manpower Resources Integration Guide for Army Materiel Development*, Aberdeen Proving Ground, Maryland; and U.S. Continental Army Command Regulation 350-100-1, *Systems Engineering of Training* (Course Design), February 1968. These and related documents provide the framework for an integrated approach to considering the man in Army man-machine systems.

HumRRO Aviation Division Research Program

I would like to review some of our ongoing research at the HumRRO Aviation Division. We are presently concentrating on four research areas: (a) the prediction of aviator performance; (b) aerial reconnaissance and surveillance systems, particularly human information processing in such systems; (c) the development of procedures to aid systems engineering of training, using aviation maintenance training as a vehicle; and (d) development of aviation training devices, simulators, and synthetic training embodying advances in both training and hardware technologies.

Within the first area, prediction of aviator performance, we are engaged in an extensive multiple-correlational study that seeks to make systematic use of the great mass of performance and descriptive data that accrues during the aviator's career. Basically, our concern is with what we call the secondary selection process, that is, the management of the man after he is selected for the aviation training program. We hope to be able to use such data to increase the accuracy with which certain criterion behaviors can be predicted. For example, we are seeking to determine what indices—background, motivational factors, training performance, and so forth—are predictive of success or failure in the flight training program. The process of "washing out" men from flight training is one with dollar implications. If we can sharpen the validity of this process, that is, increase the precision and timeliness of our pass-fail performance prediction, the Army will benefit.

We are also trying to develop predictive indices for performance during advanced training such as helicopter gunnery. Another obvious area of interest in prediction is combat performance. What are the factors that characterize the more effective combat performer? Finally, we are interested in the career retainability of the pilot. This latter factor is especially critical in manpower management due to the relatively low retention rate for first-tour pilots and the high cost of their replacement.

In the second area, that having to do with aerial reconnaissance and surveillance systems, we are engaged in a detailed analysis of human functions and actions in such systems. Our goals are the identification, assessment, and experimental study of the human functions most critical to mission success. We have adopted an information-processing model as our point of departure (Figure 1). Our interest is primarily in the perceptual-cognitive activity of the operator as he processes and utilizes information, rather than in his overt actions in operating the sensor devices or the aircraft.

Tentative Synthesis of Information Processing Functions

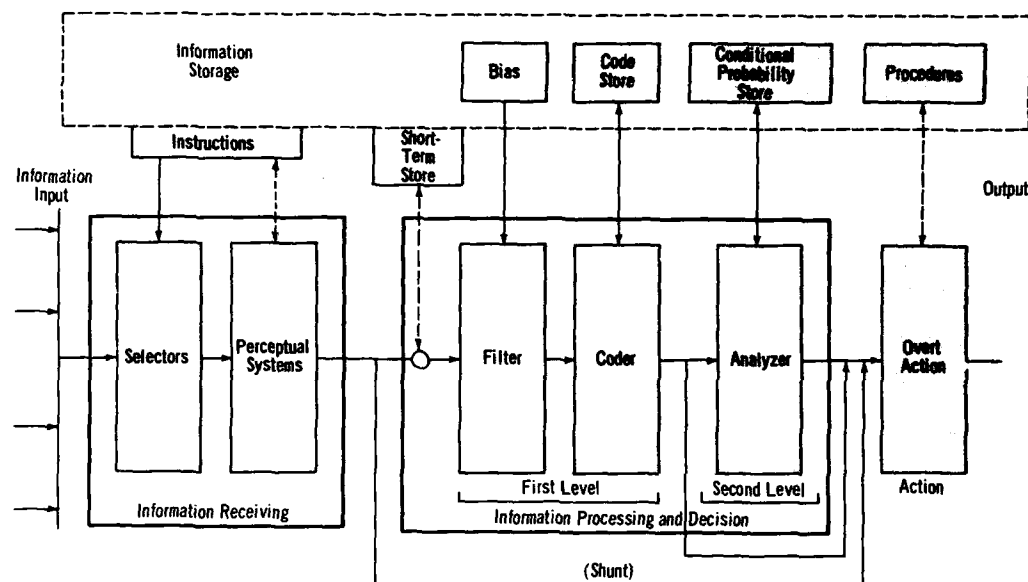


Figure 1

Our research program on systems engineering of maintenance training is aimed at the development of improved procedures for the gathering and use of job descriptive data as a basis for course design. A key aspect of systems engineering of training is the determination, in some detail, of exactly what the man does in his job, that is, what tasks he performs, how frequently, and under what conditions. We are looking at the amount and type of information return resulting from several job survey and sampling techniques. Figure 2 shows the number of UH-1 helicopter maintenance personnel—mechanics and supervisors—that we have surveyed, either on-site or by mail, at four survey locations.

Once the detailed job description data are assembled, we are seeking to develop computerized mathematical models for allocating training responsibility for each job task to the central school or to unit training.

The final major area of our research program is concerned with simulation and training devices. Over the years we have been impressed—or perhaps I might better say depressed—by the fact that advances in the simulation and device state-of-the-art have been primarily in engineering technology, rather than in training technology. We have seen vacuum tubes replaced by solid state electronics, analog computers by digital, jerky motion by smooth, horizon lines drawn on the wall by color TV visual world displays, and so forth, but the training concepts remain much the same.

In short, we have tried to make our simulation and the real world as nearly synonymous as possible. Very few device developments have

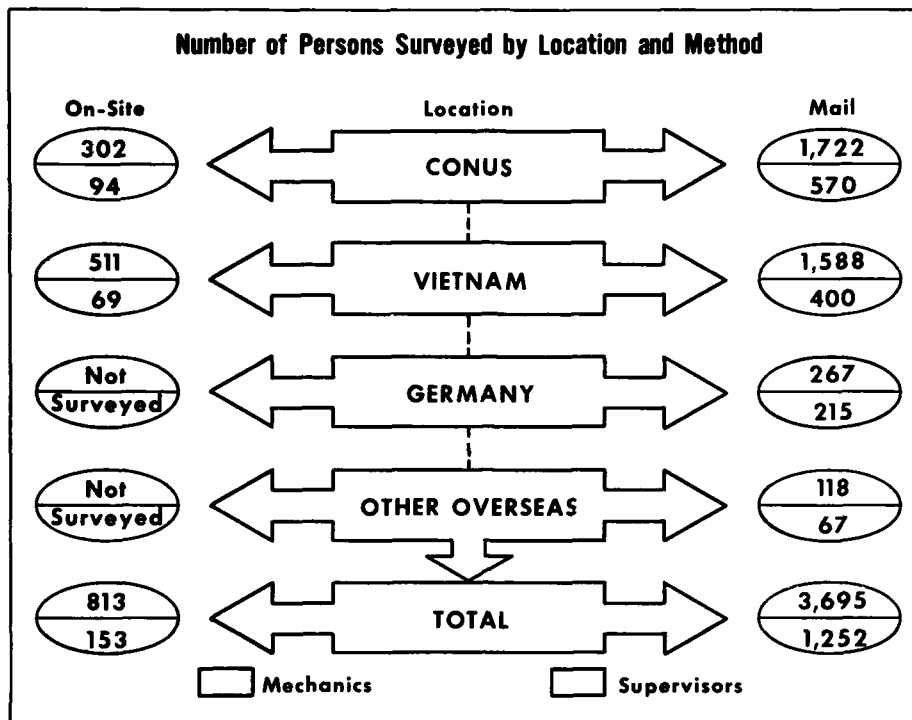


Figure 2

taken the human learner as their basic point of reference. If we make learning, rather than equipment, our point of concern, the problem becomes not that of a one-to-one simulation of the real world, but the provision of the most effective environment in which learning can take place, and in effective environment I include the concept of cost-effectiveness. The real world is often a notably inefficient environment for learning.

Let me give you a simple example. There are cockpit procedures trainers in which the trainee can learn and practice the numerous, complex procedures involved in the operation of an aircraft. Some of these training devices—such as the 2-C-9 (Figure 3), a trainer for the Army's OV-1 Mohawk aircraft—cost in excess of \$100,000. A single incorrect execution of the start procedures with a turbine engine can cause damages of that magnitude of cost. However, in analyzing what must be learned and the conditions necessary for its learning, we concluded that most such procedures can be effectively taught on low-fidelity devices such as the Mohawk cockpit mockup shown in Figure 4.

Figure 5 shows a comparison of the performance (in terms of percent error) of students trained in these two devices of widely different fidelity. On the left are shown five days of training trials in the 2-C-9 and mockup devices; on the right, the performances of these two groups in the actual Mohawk aircraft after their device training and

2-C-9 Training Device



Figure 3

Mohawk Cockpit Mockup



Figure 4

Student Performance—Percent Error on all Trials

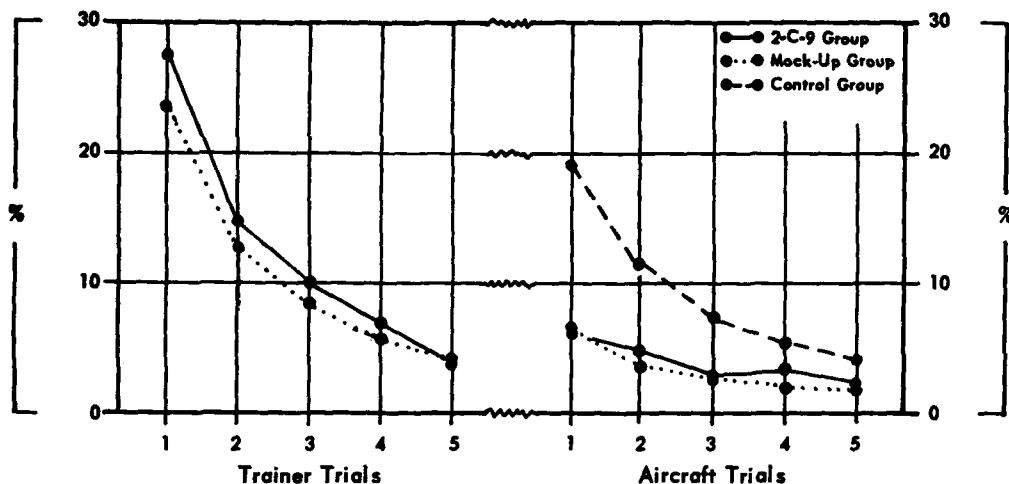


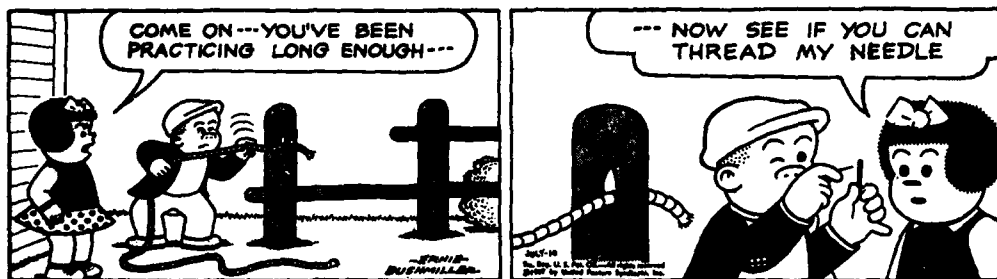
Figure 5

the performance of a control group trained only in the aircraft. The two device groups performed in equivalent fashion, both being significantly better than the control group. Thus, our research confirmed our analysis of the conditions necessary for learning, and, as a result, the Army is utilizing such low-fidelity devices at a considerable monetary savings.

The basic question in training device research is whether transferable training occurs. Mr. Bushmiller, the cartoonist, illustrates the point quite well (Figure 6).

NANCY®

By Ernie Bushmiller



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Figure 6

One of the most exciting applications of training technology on which we are working is a system of helicopter simulators called the Synthetic Flight Training System (SFTS). A contractor has been selected to develop the first prototype that will look something like the one shown in Figure 7.

Synthetic Flight Training System

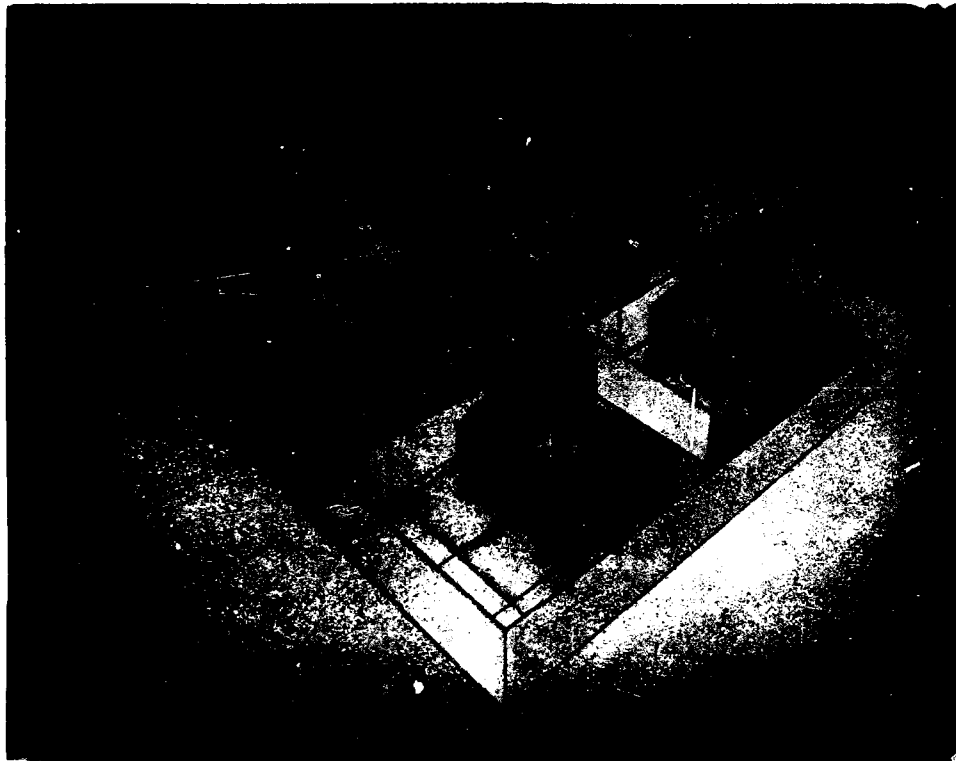


Figure 7

In the SFTS we are implementing some new training ideas such as automation of training, computer monitoring and evaluation of performance, adaptive training, and training system management. For the first time we will have devices that have been conceived and designed as a training system, rather than as a number of separate, discrete devices, each independent of the other.

I have tried with this rapid, broad-brush treatment to give an overview of the Army's human factors research program and a brief explanation of the general content of current research at the HumRRO Aviation Division.

Human Factors in Airmobility: 1970-1980

In keeping with the theme of this meeting, "Challenges for Army Airmobility," I would like to discuss some of the human factors research problems that I believe will be of particular importance during the coming decade. There are three general research areas: (a) problems that derive primarily from airmobile operational considerations; (b) problems that derive from or are centered in hardware considerations;

and (c) problems that are based in the characteristics of the human learner and the learning process itself.

Within the first area, airmobile operations, I see two problems of major concern—neither is new and, while headway has been made on each, neither has been solved. The first concerns our ability to operate under restricted visibility conditions. The full exercise of airmobility cannot be realized until we are able to extend the range of conditions under which we can fly.

Developments such as low-light TV may make it possible to fly aircraft, particularly helicopters, under illumination conditions not heretofore possible. However, we have hardly scratched the surface concerning the display and training requirements in this area. We know relatively little about how to teach helicopter control by reference to a TV display, particularly to the naive student pilot. This latter student, I believe, represents one of the significant training challenges for Army airmobility. If large-scale night airmobile operations are to be achieved, we must be able to teach such skills to our students, rather than only to the pilot with 2,000+ hours of experience.

The second operational problem area, low-level navigation, is obviously related to the first, but I am referring now primarily to day navigation by visual reference to outside cues. The Army has evolved the concept of nap-of-the-earth flight as a means of allowing the helicopter pilot to avail himself of cover afforded by the terrain and to preserve the element of surprise. However, nap-of-the-earth navigation is one of the most demanding flight tasks that can be required of the pilot. The flight path is devious, and terrain clearances are minimal. Perception and interpretation of visual cues for navigation become extremely difficult, not only because of the altered visual perspective, but also because of time compression and masking factors. At extremely low altitudes, angular velocities of terrain features moving through the visual field may become so great that the pilot is unable to perceive what the features are. Also, it may be impossible to see a navigation checkpoint—a road intersection or a building—if it is as short a distance as 50 meters from the aircraft flight path.

The Army has some sophisticated electronic navigation systems under development that will assist greatly in solution of this problem. However, it is my belief that to achieve a true nap-of-the-earth navigational capability, we will have to rely on our most sophisticated sensors and computers, the eyeballs and brains, as well as on our electronic black boxes and bugs.

The second major type of problem is hardware-centered. In the cockpit design and instrumentation area we need an increase in emphasis on the design of equipment from the point of view of training. It sometimes seems to be forgotten in the design of an aircraft that someone will have to learn to fly it. Often the trainee is an 18- to 20-year-old youth with little or no mechanical or aviation background—most of our warrant officer trainees enter the program immediately after graduating from high school. It is possible that a warrant officer pilot may reach combat prior to his 19th birthday. The question

is not the adequacy of the cockpit design and instrumentation for the test pilot or the experienced Army pilot, but how they fit the naive student.

An example may illustrate what I mean by consideration of training in design. In the AH-1G Cobra, the pilot and copilot/gunner are seated in tandem (Figure 8). The copilot/gunner, who sits in the front cockpit, has rudimentary flight control that he can use to control the aircraft in the event the pilot is disabled. In teaching students to fly this aircraft, the instructor sits in the front cockpit, while the student is in the rear cockpit. The point of concern is that the flight controls in the student cockpit possess a considerable mechanical advantage over those in the front cockpit. You can see what happens if the student freezes on the controls, in a precarious flight situation. If the fact that students must learn to fly the aircraft had been considered during design, a different decision might have been made on this feature. This type of example can be multiplied.

Another hardware factor that is going to be more and more prominent in airmobility considerations is the proliferation of black boxes in our aircraft systems. Black boxes—computers and other marvels of electronics—are wonderful, but we must recognize and be prepared to pay the price they exact. I am not referring to their direct procurement costs, but to the maintenance costs of these sophisticated

AH-1G Cobra With Front and Rear Cockpits



Figure 8

electronics systems. If we do not do the necessary planning and research for their maintenance—and I refer to both design for maintainability and consideration of the manpower and training problems for maintenance personnel—then we may find ourselves frustrated and hindered by their use.

The next research area, which will be of increasing importance to aviation training, has both a hardware and a learning orientation. I refer to the growing importance of the computer in instruction. The use of the computer in flight simulation makes it especially important to aviation training. We can now consider training techniques that were previously impossible such as those mentioned as part of the Synthetic Flight Training System.

There is a real danger that the use of the computer in instruction can simply be a means to disseminate bad instruction to more people in a shorter time. There are those who contend that this is what has taken place with much of educational TV. However, we do not need to create still another electronic "wasteland." To utilize the computer in this fashion would be tragic. We must devote the necessary research attention to the learner and the learning process if we are to realize the true potential of our new training media. We must extend our horizons as to the capabilities of new media, rather than simply trying to tailor the media to our pre-existing educational concepts. This point of view was stated at a training innovations conference by Dr. Ofiesh¹ of Catholic University:

An engineer, the moment he has a new means of solving his problem, will take that means, but the profession of education and training, as long as they consider the means outside their area of purview, back away from it. In fact, educators are the one profession I know that is reluctant to work with any other professions. It's part of our provincialism and part of our failing. But as long as we are oriented towards the problem of producing learning or changing or modifying behavior, and that's all learning's about, that's our goal. Our goal is to change people; to modify their behavior; to develop competencies where there are none; skills where there are none. We should be willing to put into our arsenal of tools any that technology has available to us or that may appear on the horizon.

Turning to our last problem area, the people problems, I think the next decade will see the devotion of more research time to the learner as an individual. In our manpower management—recruiting, training, and assignment—we are going to have to consider more carefully the numbers and kinds of learners entering the military. There will be more concern over the effects of the civilian social climate on the attitudes of the young men entering the services. It is obvious that

¹Gabriel D. Ofiesh, "System Approach to Training," *Report of the First USCONARC Training Innovations Conference*, U.S. Army Infantry Center, Fort Benning, Georgia, September 1968.

we are in the midst of some extensive and important changes in our society. For the military psychologist (and the military commander, I might add) to ignore these changes would be as foolish as for the commander to ignore changes in hardware technologies or in potential enemy tactics.

Of particular concern in the aviation field are the aptitudes of our trainees. I have already mentioned task difficulty, electronics maintenance, and the high costs of aviation training as factors of concern. We need more research on selection of personnel for these complex training programs and on how best to utilize them. Our pool of high-aptitude personnel is not unlimited.

A related area of research during the 1970s will be the individualization of instruction. There is already a definite trend away from the rigid, lockstep approach in military training. This individualization process has both training and social implications. Training research developments such as programmed instruction and computer-assisted instruction allow for much individualization, but we need to know more about factors such as perceptual style or learning style in order to tailor instruction. We need to determine the best instructional strategies for different levels and constellations of aptitudes. While we may, thus, individualize our instruction, we will still desire that the performance capabilities of our graduates meet specific, defined standards. As one of my HumRRO colleagues¹ has stated: "If at some point in time you wish people to be different, then treat them the same; if you want them to be alike, then treat them differently." Dr. McFann was pointing out that instruction must recognize individual differences.

A final area of research concern for the 1970s is study of the learning process itself, particularly the learning of complex perceptual-motor skills. Good starts have been made in this area—factor analytic studies of motor skills, behavioral taxonomies, and so forth—but we need a much better understanding of the fundamental process if we are to engineer behavior effectively and efficiently. This need for better understanding applies to some seemingly simple problems. For example, one of our knottiest problems in aviation is simply that of measuring performance validly and reliably. Sound measurement is a necessary step in understanding the learning process, but we have a long way to go in this area.

In summary, then, the Army has mounted a broad human factors research and applications program showing its clear recognition of the critical importance of the human factor. I have emphasized aspects of the program related to airmobility, but the program is aimed at all types of Army operations. We are currently doing many interesting things, but the research possibilities for the coming decade appear even more exciting.

¹Howard H. McFann, "Individualization of Army Training," *Report of the First USCONARC Training Innovations Conference*, U.S. Army Infantry Center, Fort Benning, Georgia, September 1968; in HumRRO Professional Paper 6-69, February 1969.

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<p>This paper describes the general organization of the Army Human Factors and Social Science Research Program and its principal research agencies, and discusses current research activities of HumRRO Division No. 6 (Aviation). These activities include studies of prediction of aviator performance, systems engineering of aviation maintenance training, human information processing functions in aerial reconnaissance and surveillance systems, and aviation simulation and training device requirements. Selected human factors research areas of significance to Army airmobility during the 1970-1980 period are also discussed. These are grouped under problems related to airmobile operational considerations, hardware considerations, and human learning considerations.</p>		

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